Digital Computer Laboratory
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SUBJECT: <u>GROUP 63 SEMINAR ON MAGNETISM VII</u>

To: Group 63

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In the previous lecture we introduced Weiss' notion of the internal field. The energy producing this field is of the order MH, where H is the internal field. The thermal energy needed to overcome this energy is attained at the Curie temperature θ_c, above which the material becomes paramagnetic. Since the thermal energy at the temperature θ is $k\theta$, where k = Boltzmann's constant, we may say that MH is of the same order of magnitude as $k\theta$.

Thus

$$MH \sim k\theta_c$$

$$H \sim \frac{k\theta_c}{M}$$

where $k = 1.4 \times 10^{-16}$ erg/degree

M = Magnetic moment of electron

$\sim 10^{-20}$ ergs/oersted

$\theta_c \sim 1000^\circ$ Kelvin

Therefore

$$H \sim \frac{10^{-16} \times 10^{3}}{10^{-20}} = 10^{7} \text{ oersteds}$$

Since the magnetic field arising classically from the magnetic moment of a neighboring electron is of the order of 10^3 oersteds, there was a great deal of difficulty in determining the origin of this tremendous field. This problem was discussed in the previous lecture, and the field was found to be due to exchange forces arising from interchange interactions.

This internal field leads to a finite value of the intensity of magnetization for a ferromagnetic material even when no external field is applied. One might then ask why it is possible to find an unmagnetized piece of iron at room termperature. Answering this question led Weiss to the concept of magnetic domains.

He assumed the material consisted of a large number of very small regions called domains. These domains are highly magnetized, but are so oriented relative to each other than the material as a whole appears unmagnetized.

This assumption was confirmed by Barkhausen in 1919. He discovered that in a hysteresis loop (figure 6) the change in the magnetization of iron occurs in finite jumps in the steep portion of the curve. This showed the magnetization increase to be due to a series of domain changes.

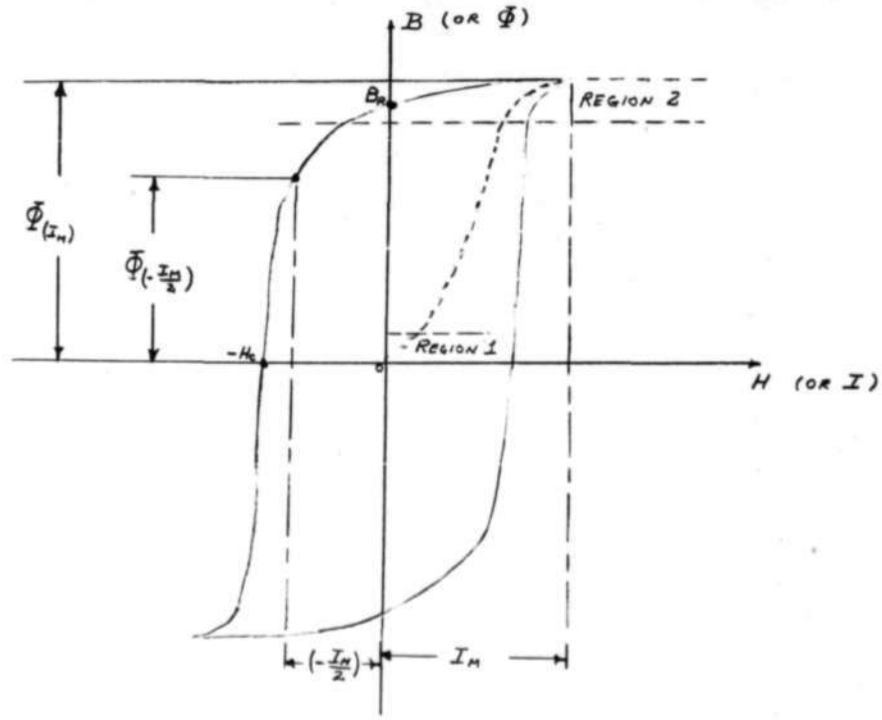

Figure 6

Before continuing with domain theory, a number of terms will be defined with the help of the hysteresis loop shown in figure 6. These loops are usually plotted as magnetic induction, B, versus magnetic field, H, curves; but since the quantities measured directly are the flux, Φ, and the current, I, these quantities are sometimes used.

Then we define:

B_r = Remanance

= Magnitude of induction for $\vec{H} = 0$

H_c = Coercive force

= Magnitude of magnetic field for $\vec{B} = 0$

I_m = Maximum value of current during hysteresis cycle

$$R = \text{Squareness Ratio} = \frac{\Phi_{(I_m/2)}}{\Phi_{(I_m)}} = \frac{\text{Flux value at } I = \frac{I_m}{2}}{\text{Flux value at } I = I_m}$$

We have previously dealt with the permeability μ, where

$$\mu = \frac{B}{H}$$

However, this is not too useful for a ferromagnetic material where μ would be varying greatly in different regions of the hysteresis loop. For this reason we define a differential permeability μ,

$$\mu_\delta = \frac{\partial B}{\partial H} \qquad \text{(VII-1)}$$

The differential permeability is therefore related to the previously defined permeability by the equation

$$\mu_\delta = \frac{\partial(\mu H)}{\partial H} = \mu + H\frac{\partial \mu}{\partial H} \qquad \text{(VII-2)}$$

If the field is kept constant at some point in the hysteresis loop, and a small field strength increment, ΔH, is applied, there will be a resultant magnetic induction variation, ΔB. This incremental line will not lie on the hysteresis loop, and therefore

$$\mu_\Delta = \frac{\Delta B}{\Delta H}$$

defines a third quantity, called the incremental permeability.

If the driving current of the hysteresis loop were reversed before reaching I_m, a smaller hysteresis loop would result. All loops of this type, which are not driven to saturation, are called minor loops.

Bitter developed a technique for "seeing" domains. A colloidal suspension of a finely divided ferromagnetic material such as magnetite is placed on the surface of the ferromagnetic material being studied. The colloidal particles then tend to gather at the domain boundaries. These patterns showed that the Barkhausen results led to a domain size that was too small. It was, therefore, decided two things could cause magnetization. They are domain growth and domain rotation.

Domain Growth

Domain growth can be either reversible or irreversible. The reversible growth occurs in the region 1 of figure 6, while the steep portion of the loop represents the region of irreversibility.

The magnitude of the field strength over which the permeability is reversible is determined by the distance a domain boundary may move before passing a peak in the energy versus boundary position curve. Thus in figure 7, a boundary may move reversibly from point I to point II, but past this position the motion is irreversible.

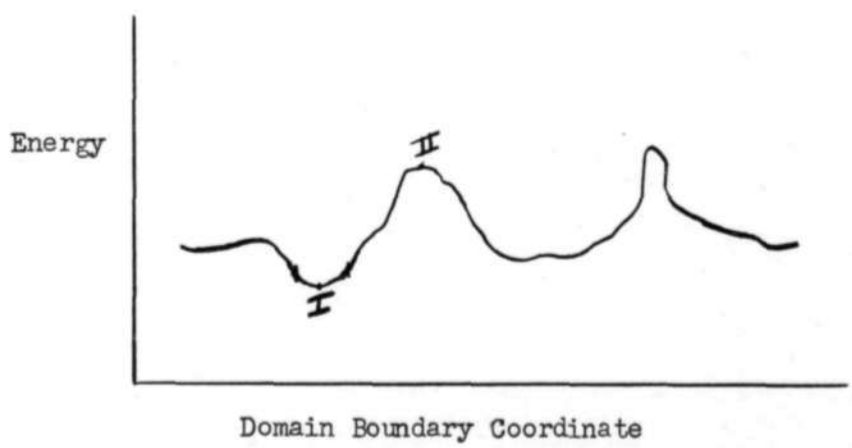

Figure 7

Domain Rotation

Domain rotation is the usual method of magnetization change in a strong magnetic field, and it is a reversible process (region 2 of figure 6).

These two methods of magnetization change are illustrated in figure 8 for an external field $\vec{H}_e$ directed as shown.

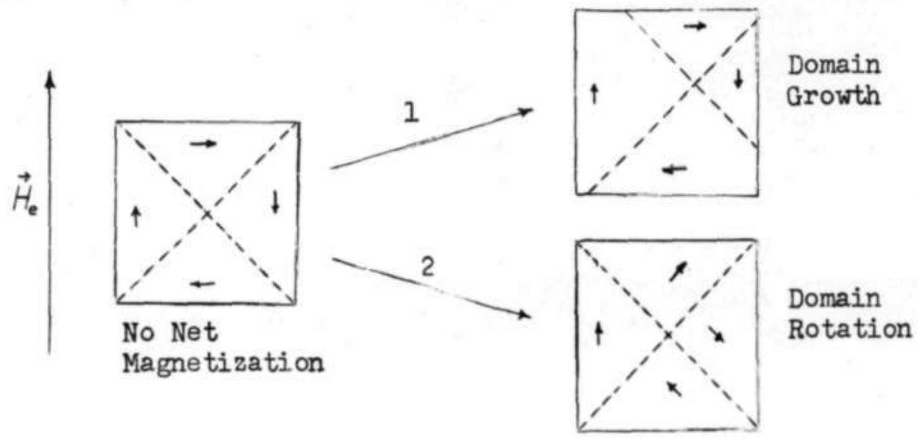

Figure 8

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